Simulating ozone in the near-tropopause region with the GMI combined model of the stratosphere and troposphere

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Study Goals:

- Evaluate capability of combined strat/trop CTM to reproduce observed near tropopause ozone distributions
- Evaluate model physicochemical processes regulating near-tropopause ozone distributions

Motivation

- Near tropopause region is important, complex, and poorly understood
  - Insufficient measurements to build global picture
  - Modeling region requires tropopause-spanning model
- Anticipated new measurement capability in region (AURA) will drive increased scrutiny
- Need to develop and evaluate appropriate global modeling capability in preparation for new measurements
- Logan profile ozone database provides unique opportunity for evaluation of near tropopause region.

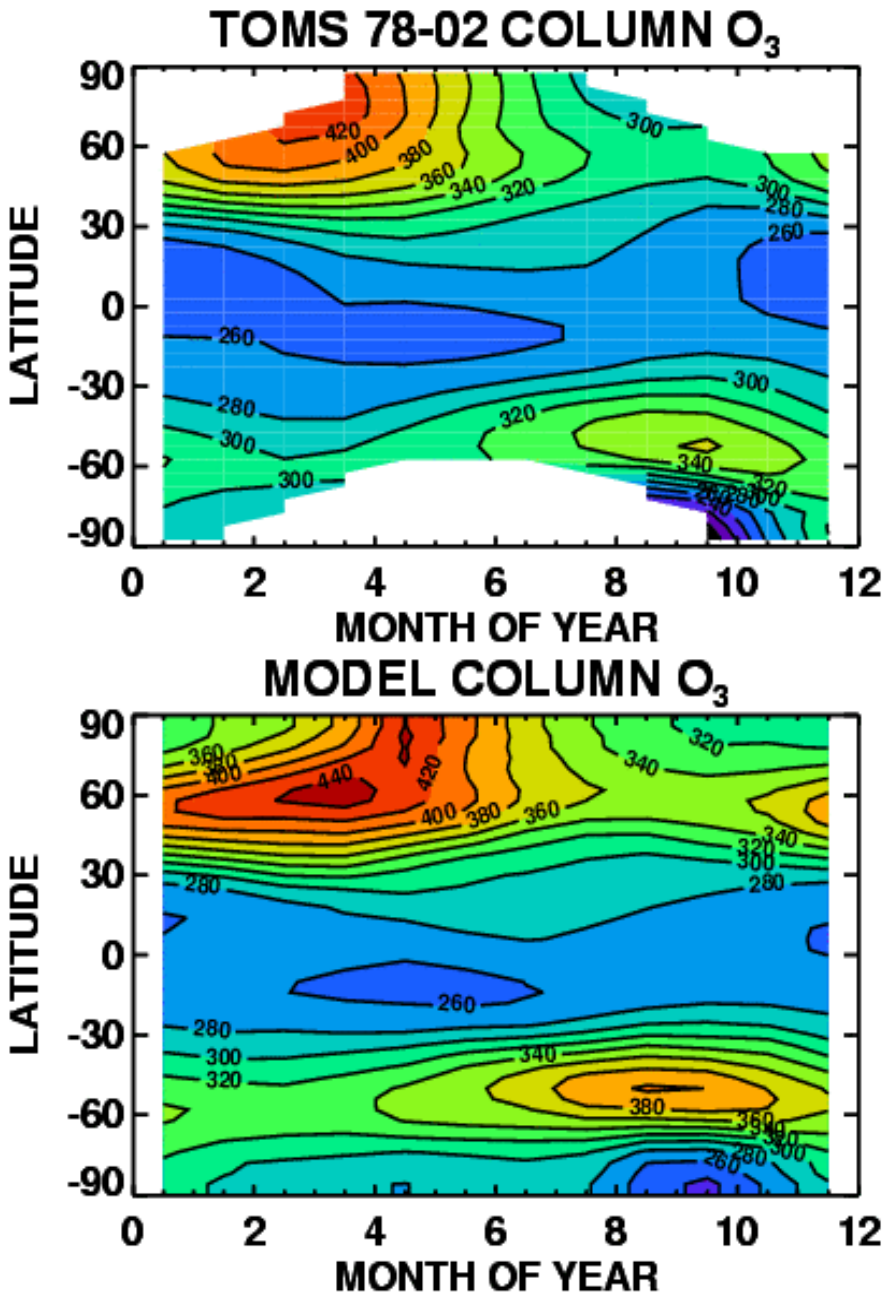
Logan Ozonesonde Climatology

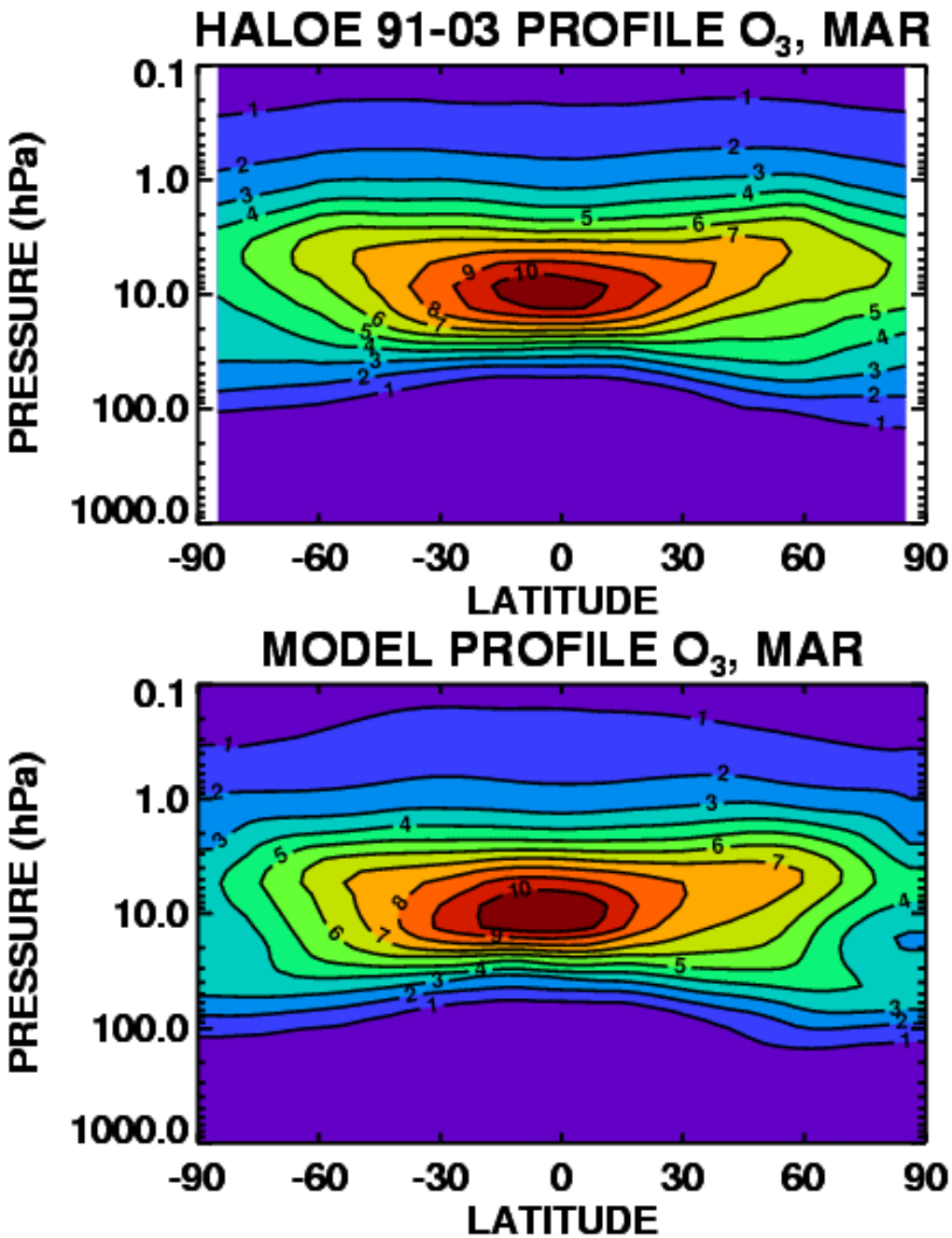
- Monthly averaged ozone profiles referenced to thermal tropopause (lapse rate, not cold point tropopause)
- Profiles interpolated to1 km resolution before averaging
- Range: -6 km to +6 km (sometimes +12 km)
- Includes standard deviation and number of soundings for each monthly average
- Sonde data from 24 sites: 8 tropical, 11 midlatitude, 5 high latitude
- Sondes accumulated between 1978 and 2002, but stations differ in time periods and number of sondes in average

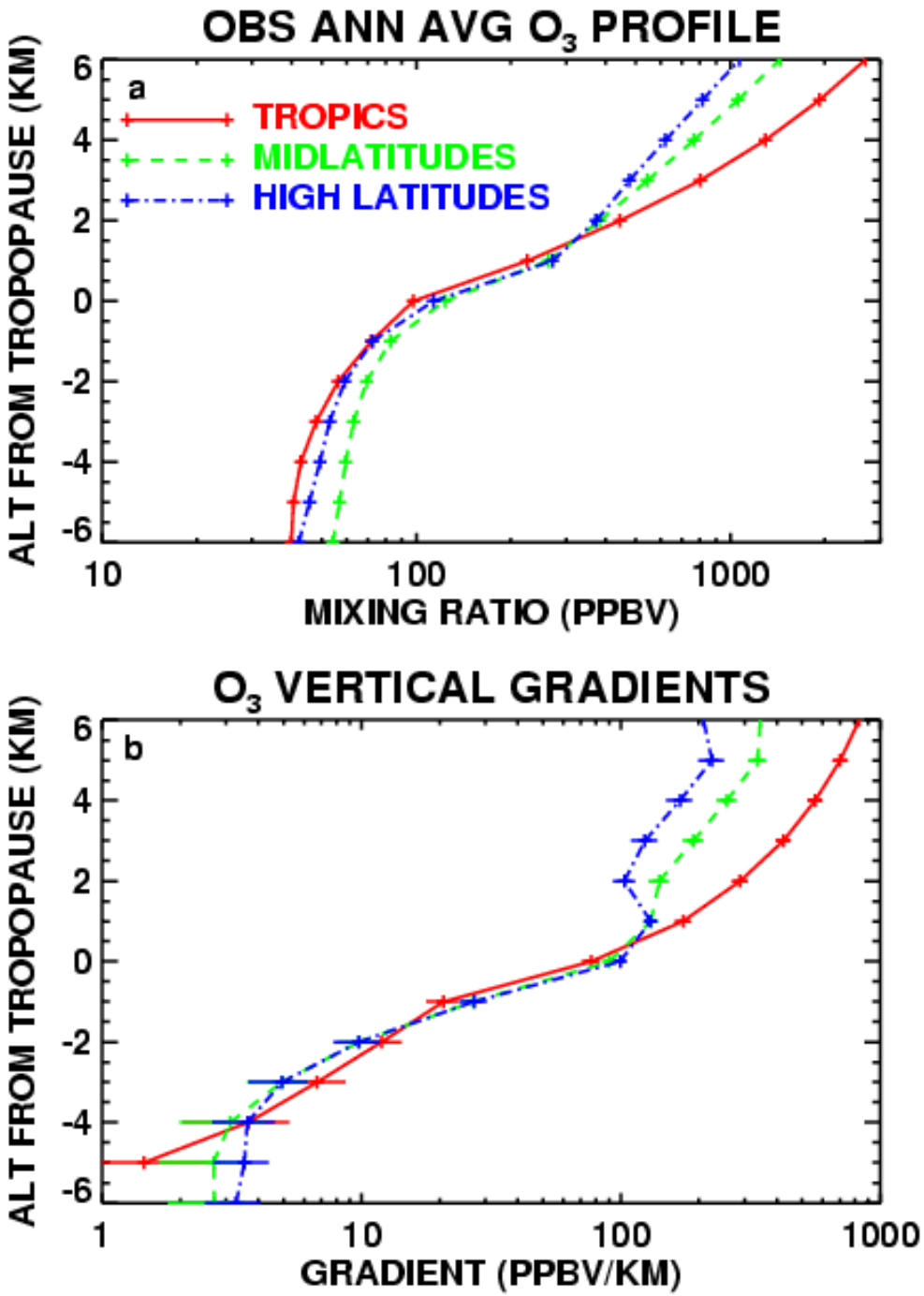
- Reference: Logan, J., An analysis of ozonesonde data for the troposphere: Recommendations for testing 3-D models and development of a gridded climatology for tropospheric ozone, JGR 104, 16,115-16,149, 1999.

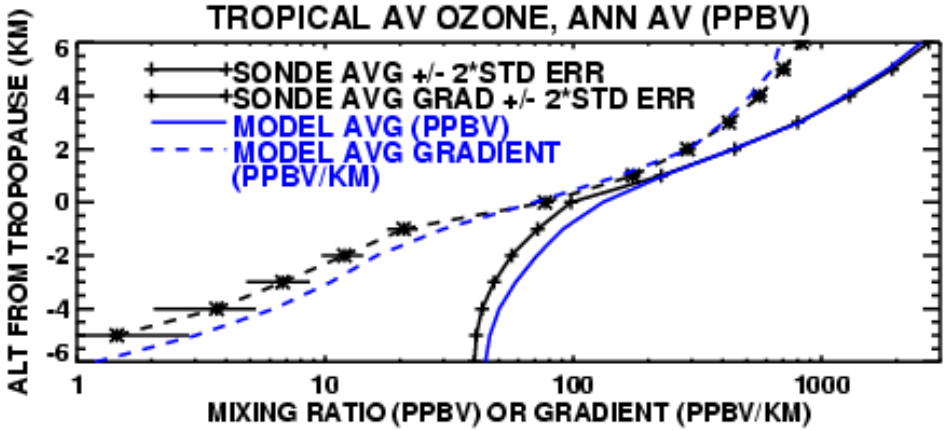
GMI combined strat/trop model description

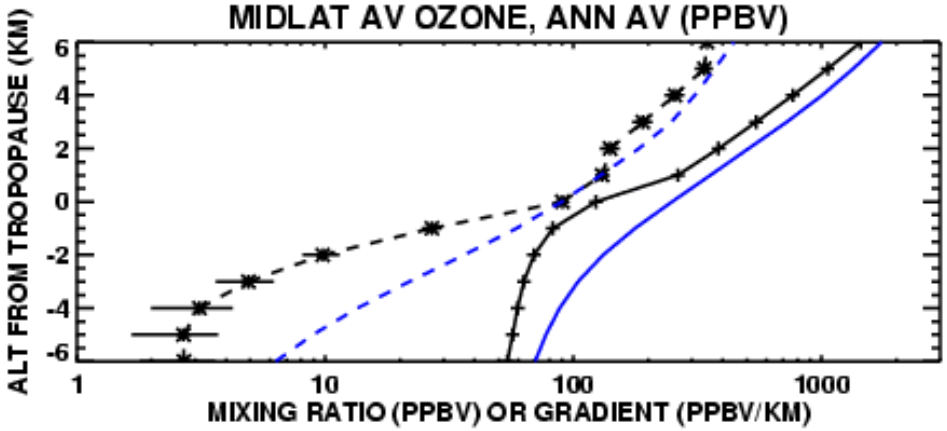
- Chemistry and transport model
- NCAR MACCM3 GCM meteorological data
- 5^{o} lon x 4^{o} lat x 52 hybrid σ-P levels, .0047 hPa top
- Vertical resolution ~1.2 km at tropopause
- Wet and dry deposition, and convective scavenging params
- Lin and Rood flux-form semi-Lagrangian advection
- 125 species combined strat/trop chemical mechanism
  including inorganic chlorine & bromine, NMHCs,
  322 thermal reactions, 82 photolytic decompositions,
  Type Ia (NAT) and II (ice) PSCs, & background LBS
- SMVGEAR II chemical solver
- Kawa lookup table clear sky photolysis coefficients to ground
- Climatological water vapor in strat, met field water vapor in trop
- Model run for 3 years, 3rd year analyzed

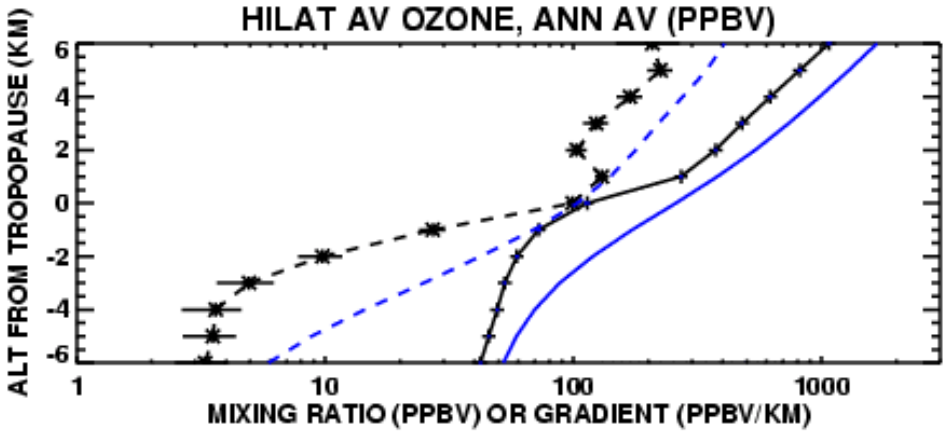

TOMS 78-02 COLUMN O_3
LATITUDE
90
60
30
0
-30
-60
-90
0
2
4
6
8
10
12
MONTH OF YEAR
420
400
380
360
340
320
300
280
260
MODEL COLUMN O_3
LATITUDE
MONTH OF YEAR
440
420
400
380
360
340
320
300
280
260

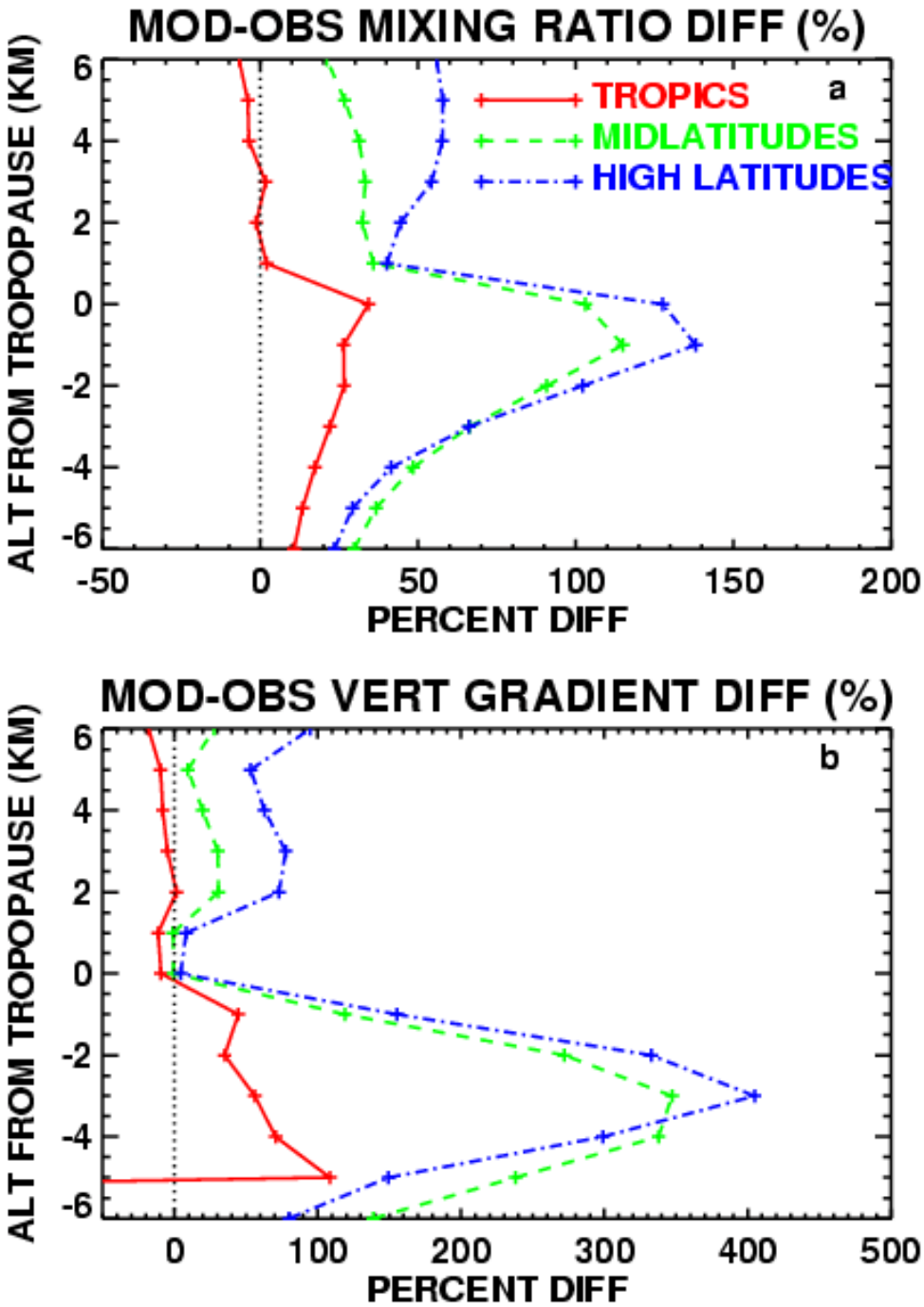

HALOE 91-03 PROFILE O_3, MAR
PRESSURE (hPa)
0.1
1.0
10.0
100.0
1000.0
-90
-60
-30
0
30
60
90
LATITUDE
MODEL PROFILE O_3, MAR
PRESSURE (hPa)
0.1
1.0
10.0
100.0
1000.0
-90
-60
-30
0
30
60
90
LATITUDE

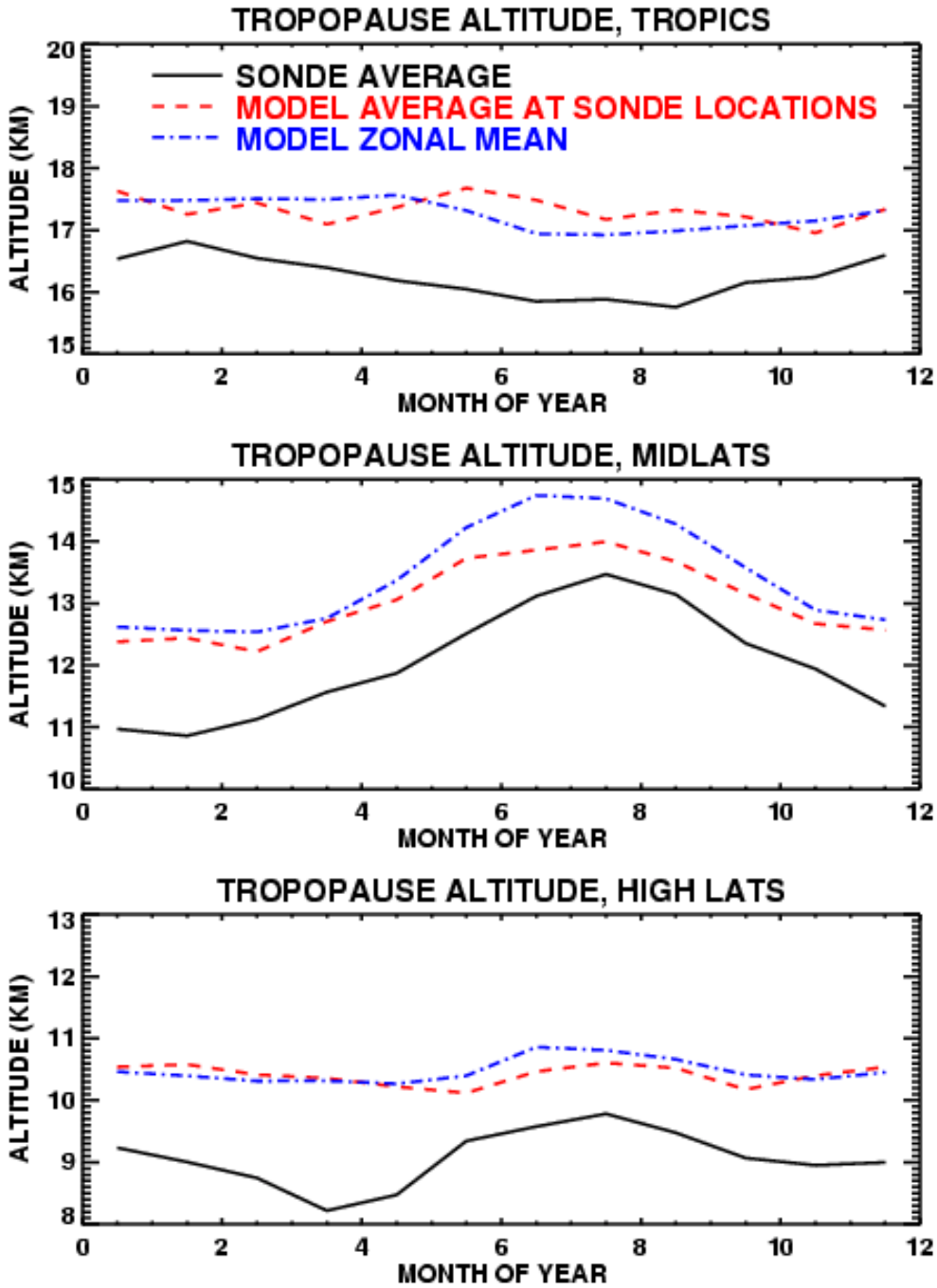

OBS ANN AVG O_3 PROFILE
a
TROPICS
MIDLATITUDES
HIGH LATITUDES
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
10
100
1000
MIXING RATIO (PPBV)
O_3 VERTICAL GRADIENTS
b
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
1
10
100
1000
GRADIENT (PPBV/KM)

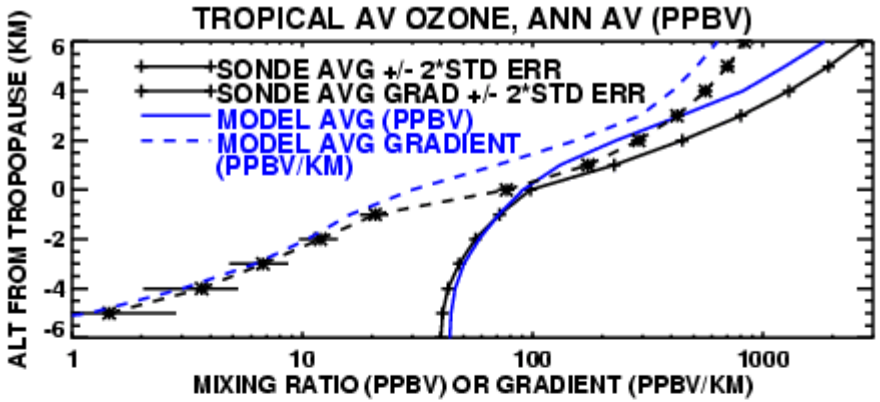

TROPICAL AV OZONE, ANN AV (PPBV)
SONDE AVG +/- 2*STD ERR
SONDE AVG GRAD +/- 2*STD ERR
MODEL AVG (PPBV)
MODEL AVG GRADIENT (PPBV/KM)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)

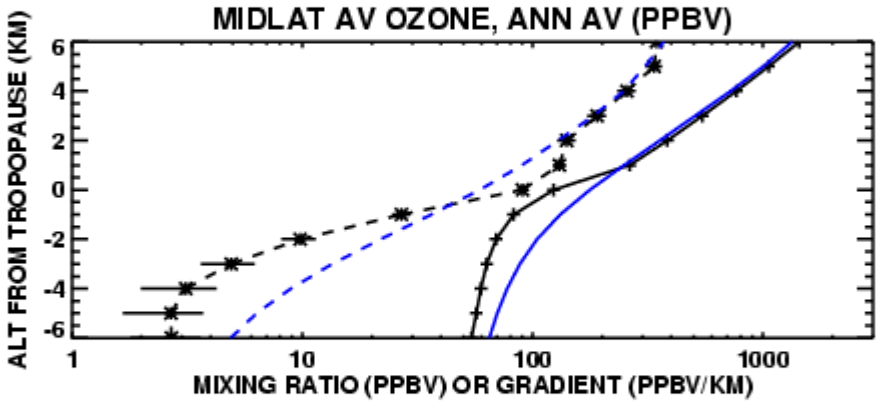

MIDLAT AV OZONE, ANN AV (PPBV)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)

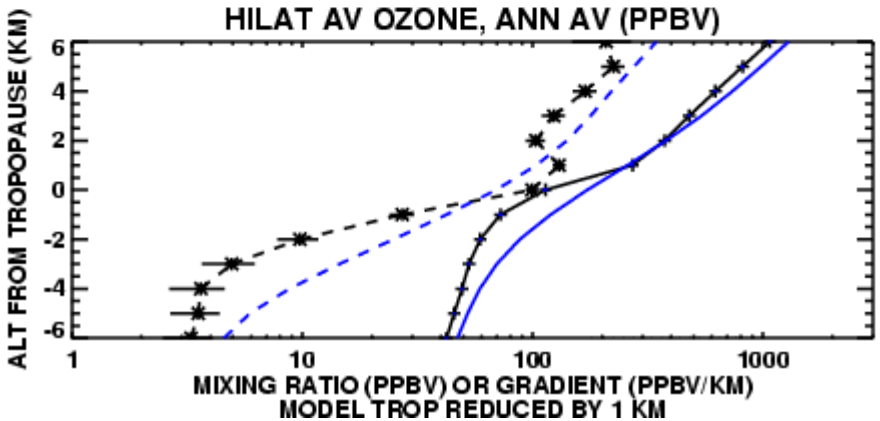

HILAT AV OZONE, ANN AV (PPBV)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)

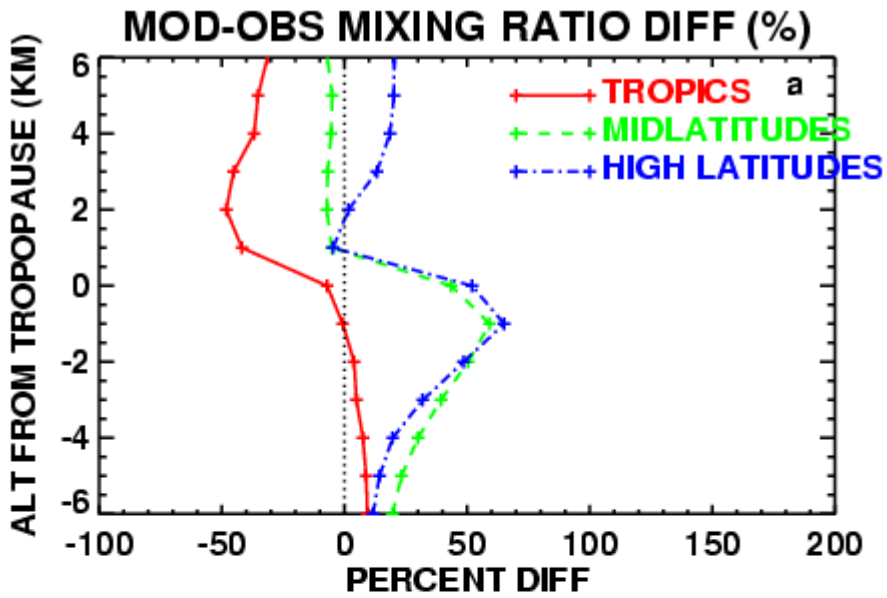

MOD-OBS MIXING RATIO DIFF (%)
TROPICS
MIDLATITUDES
HIGH LATITUDES
a
ALT FROM TROPOPAUSE (KM)
PERCENT DIFF
MOD-OBS VERT GRADIENT DIFF (%)
b
ALT FROM TROPOPAUSE (KM)
PERCENT DIFF

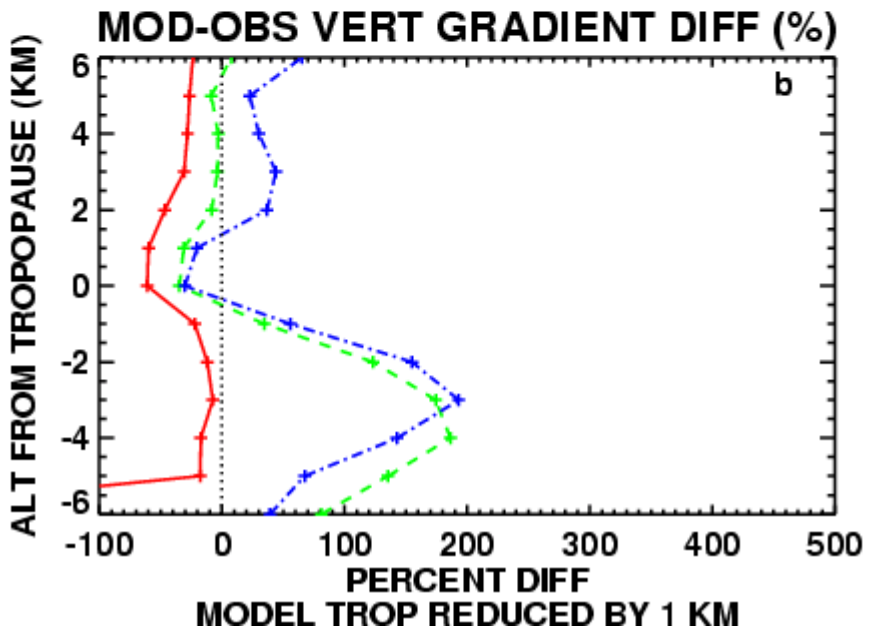

TROPOPAUSE ALTITUDE, TROPICS
SONDE AVERAGE
MODEL AVERAGE AT SONDE LOCATIONS
MODEL ZONAL MEAN
ALTITUDE (KM)
MONTH OF YEAR
TROPOPAUSE ALTITUDE, MIDLATS
ALTITUDE (KM)
MONTH OF YEAR
TROPOPAUSE ALTITUDE, HIGH LATS
ALTITUDE (KM)
MONTH OF YEAR

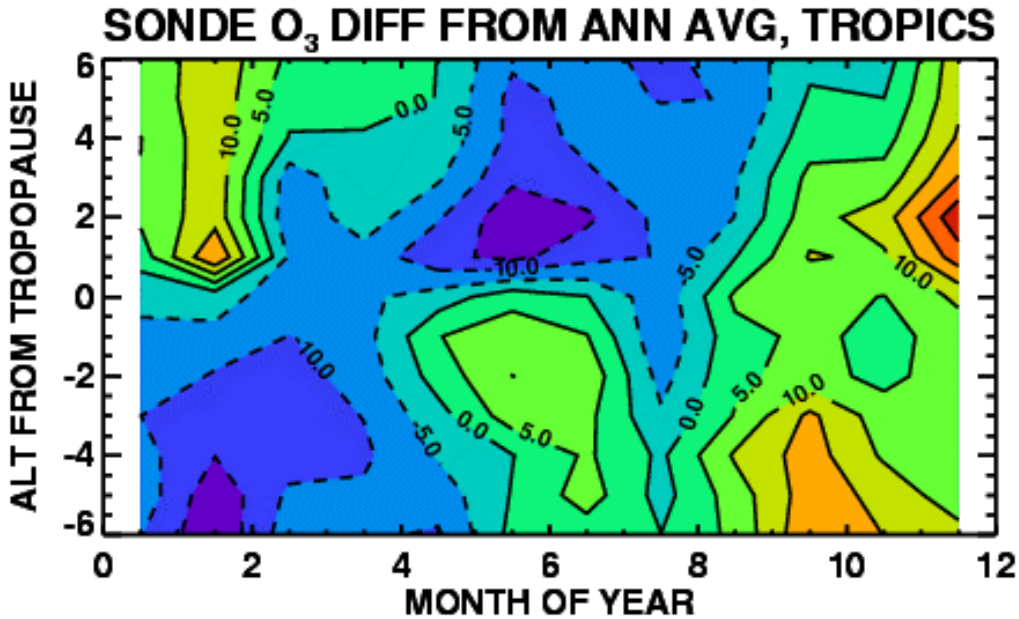

TROPICAL AV OZONE, ANN AV (PPBV)
SONDE AVG +/- 2*STD ERR
SONDE AVG GRAD +/- 2*STD ERR
MODEL AVG (PPBV)
MODEL AVG GRADIENT (PPBV/KM)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)

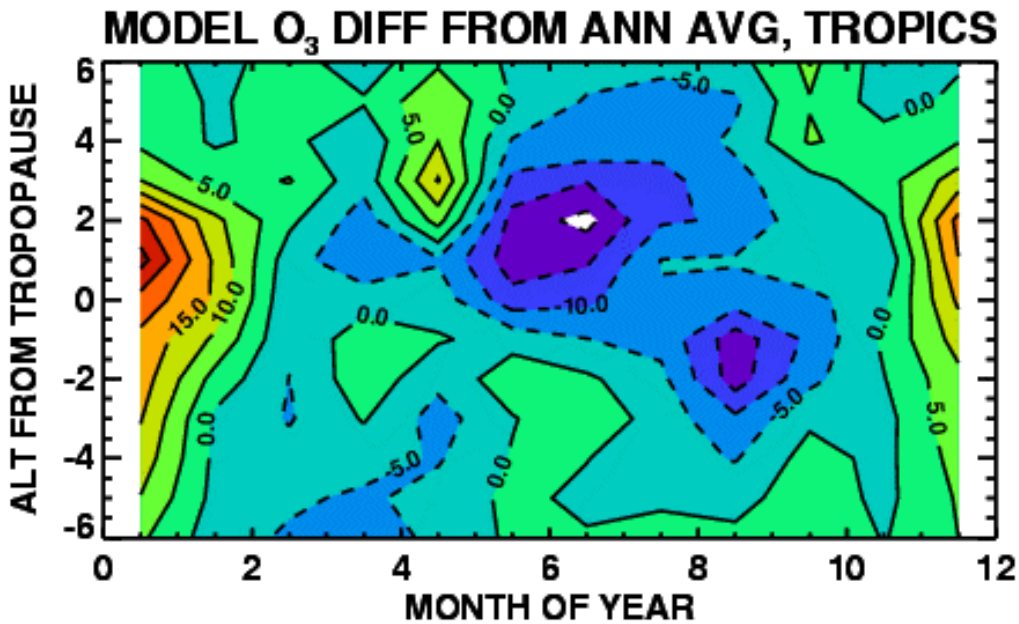

MIDLAT AV OZONE, ANN AV (PPBV)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)

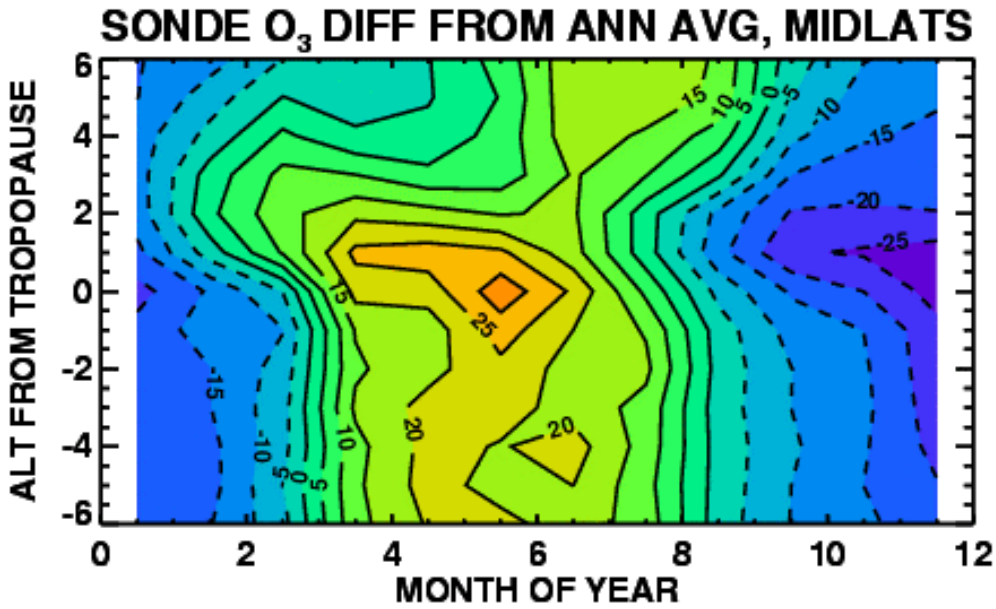

HILAT AV OZONE, ANN AV (PPBV)
ALT FROM TROPOPAUSE (KM)
MIXING RATIO (PPBV) OR GRADIENT (PPBV/KM)
MODEL TROP REDUCED BY 1 KM


MOD-OBS MIXING RATIO DIFF (%)
TROPICS
MIDLATITUDES
HIGH LATITUDES
a
ALT FROM TROPOPAUSE (KM)
PERCENT DIFF


MOD-OBS VERT GRADIENT DIFF (%)
b
ALT FROM TROPOPAUSE (KM)
PERCENT DIFF
MODEL TROP REDUCED BY 1 KM


SONDE O_3 DIFF FROM ANN AVG, TROPICS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
10.0
5.0
0.0
-5.0
-10.0


MODEL O_3 DIFF FROM ANN AVG, TROPICS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
15.0
10.0
5.0
0.0
-5.0
-10.0


SONDE O3 DIFF FROM ANN AVG, MIDLATS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
15
10
5
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-5
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-15
-20
-25
25
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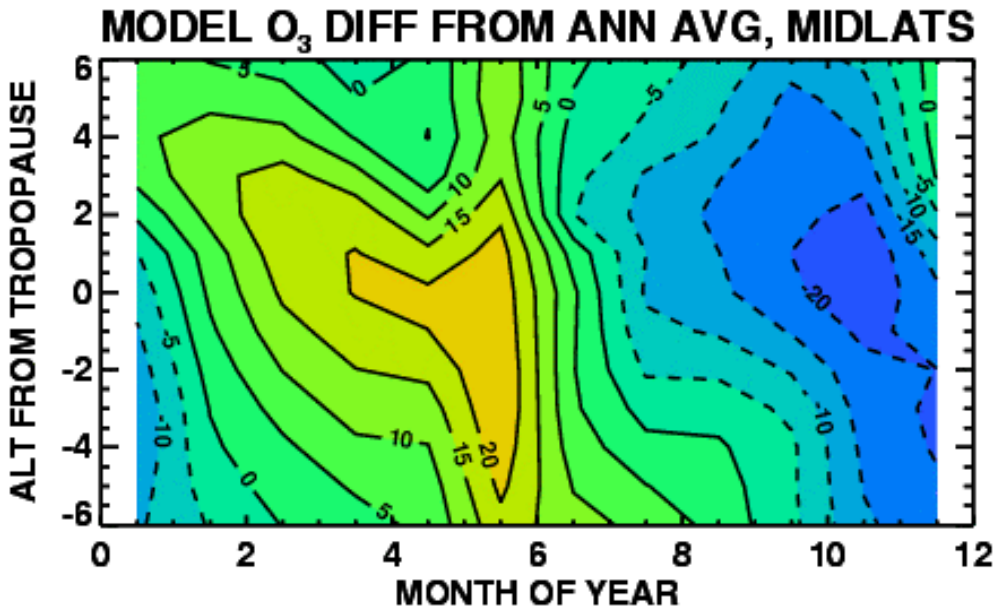
-5
-10
-15


MODEL O3 DIFF FROM ANN AVG, MIDLATS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
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-2
-4
-6
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2
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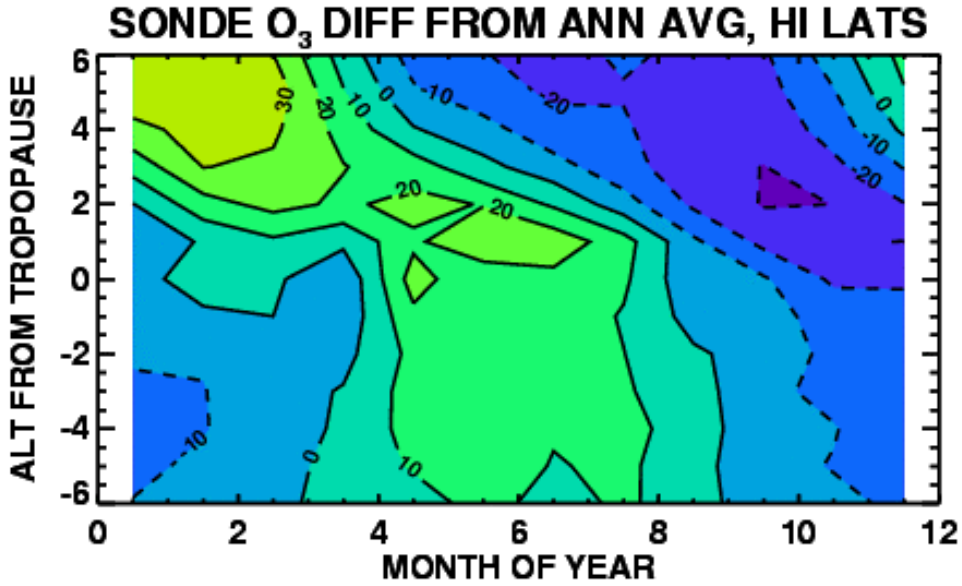
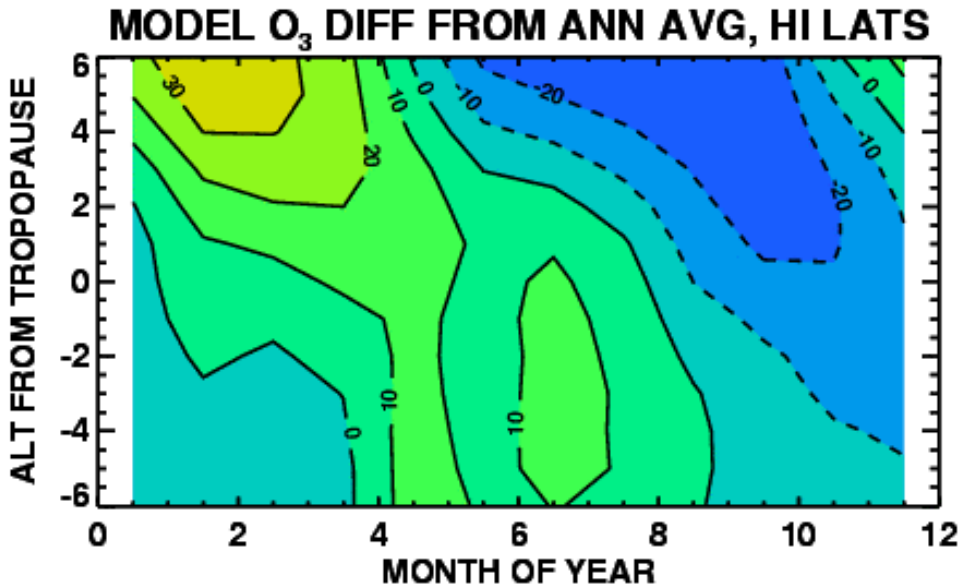
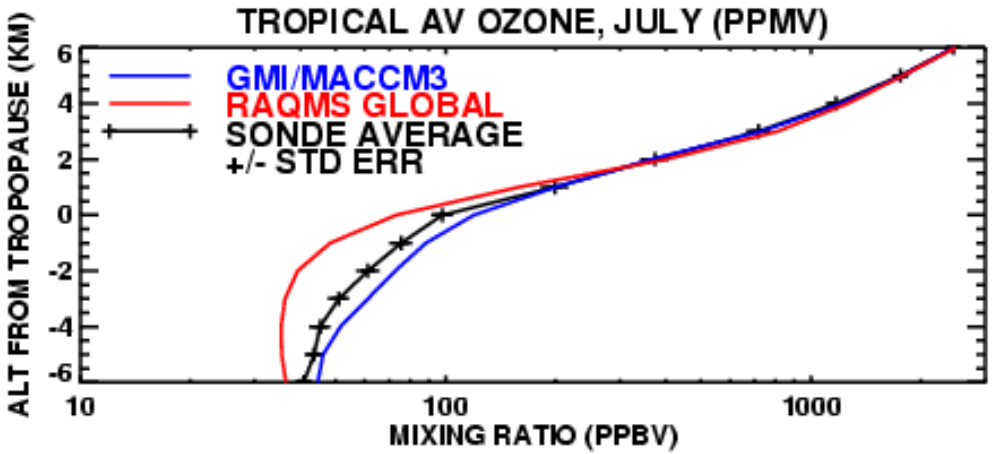
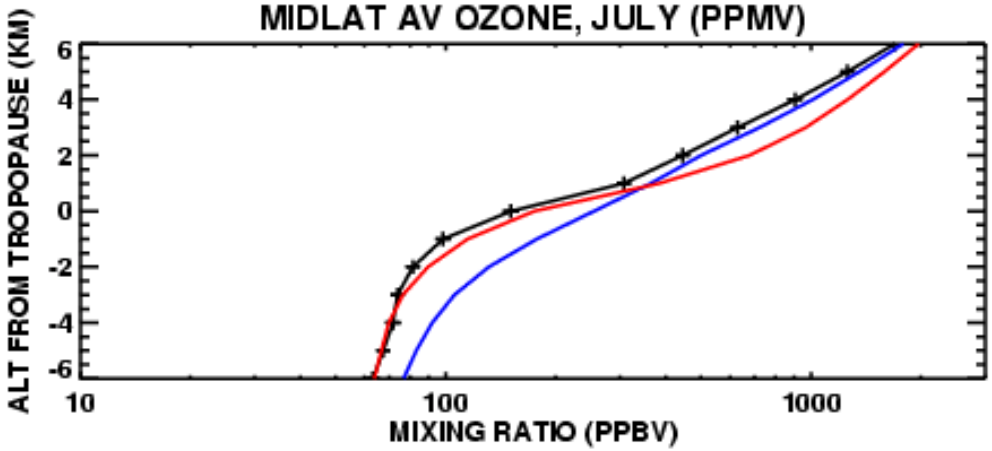
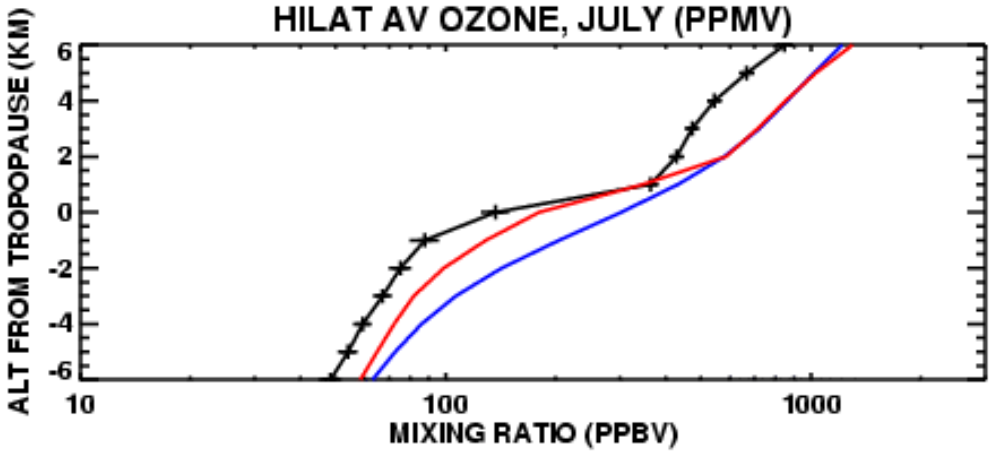
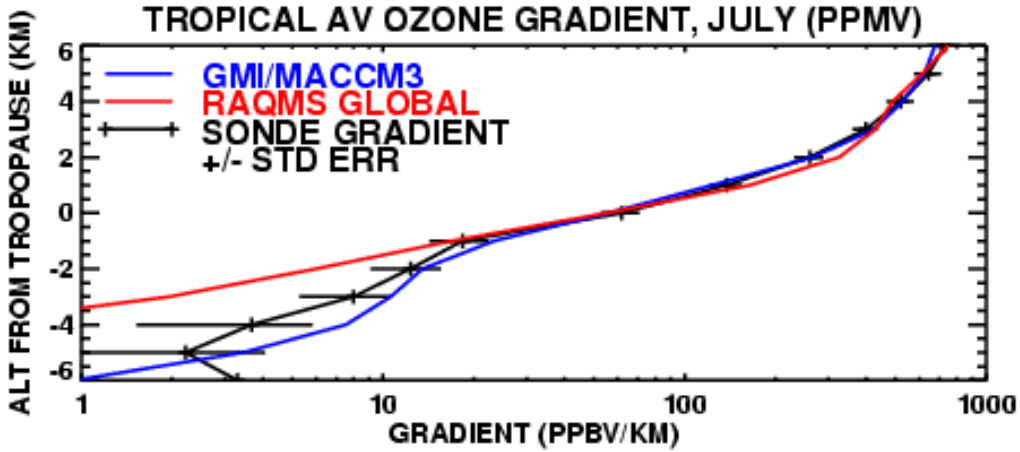

SONDE O_3 DIFF FROM ANN AVG, HI LATS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
30
20
10
0
-10
-20

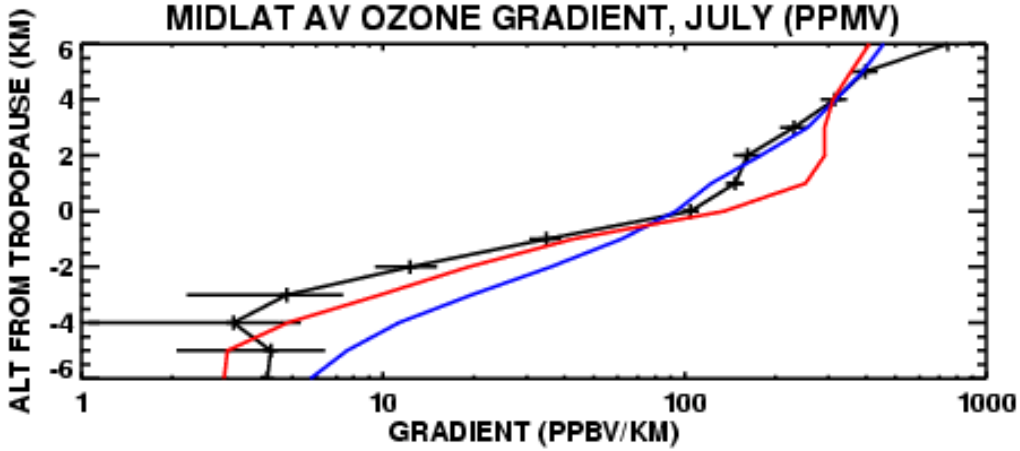

MODEL O_3 DIFF FROM ANN AVG, HI LATS
ALT FROM TROPOPAUSE
MONTH OF YEAR
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
30
20
10
0
-10
-20

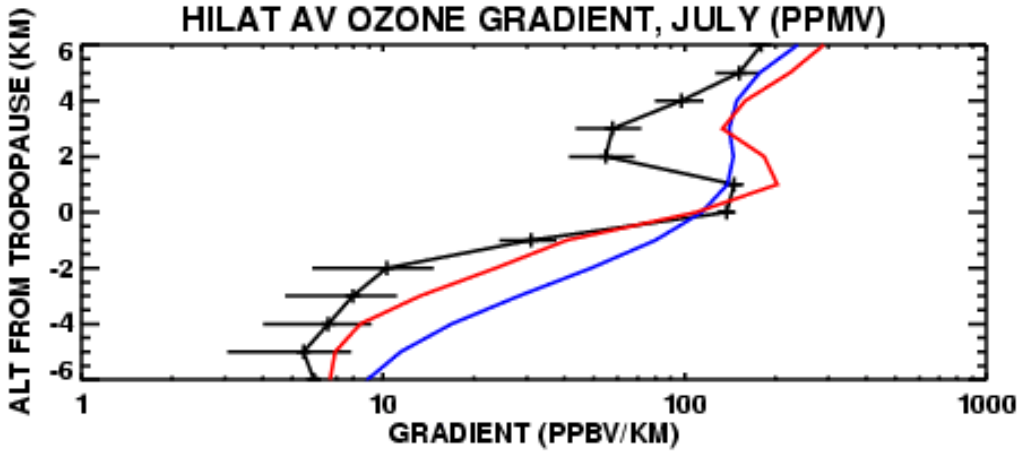

TROPICAL AV OZONE, JULY (PPMV)
GMI/MACCM3
RAQMS GLOBAL
SONDE AVERAGE
+/- STD ERR
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
10
100
1000
MIXING RATIO (PPBV)

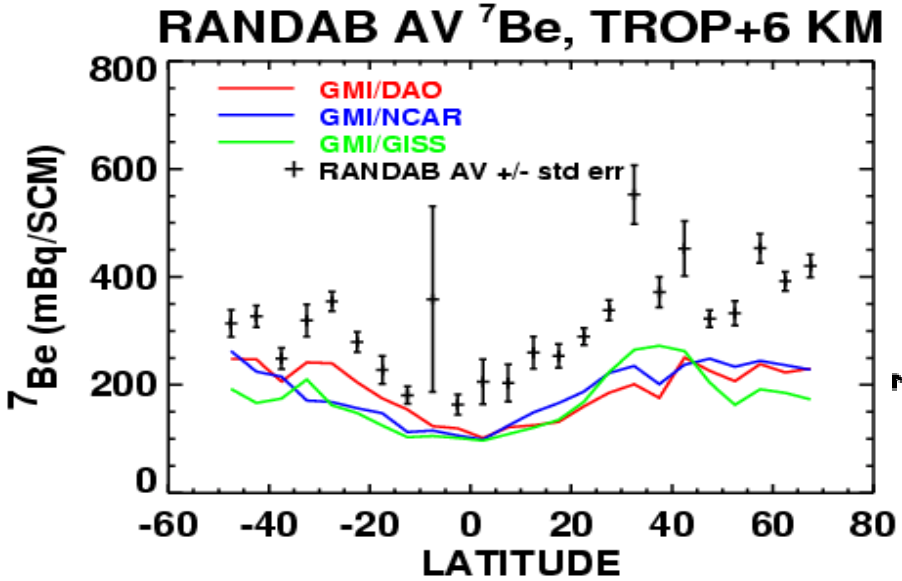

MIDLAT AV OZONE, JULY (PPMV)
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
10
100
1000
MIXING RATIO (PPBV)

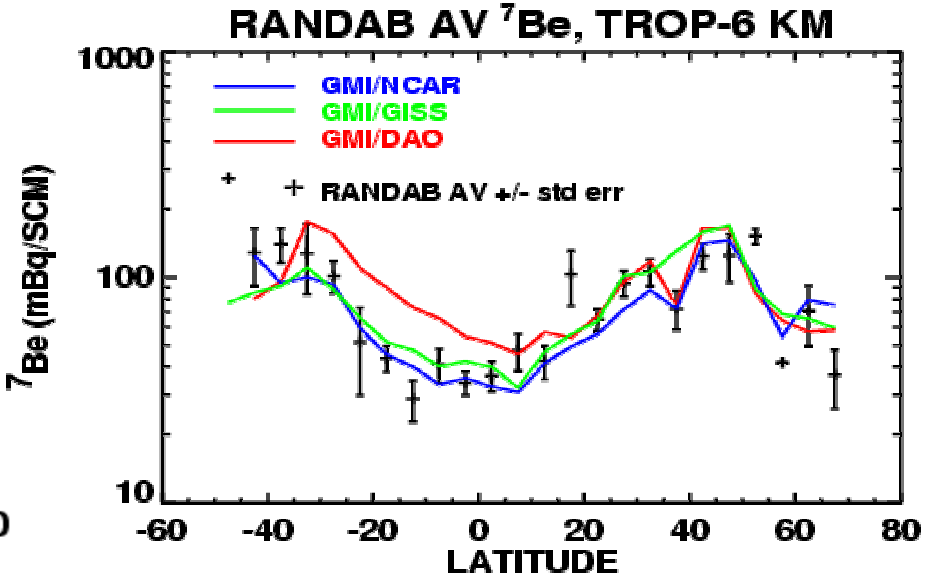

HILAT AV OZONE, JULY (PPMV)
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
10
100
1000
MIXING RATIO (PPBV)

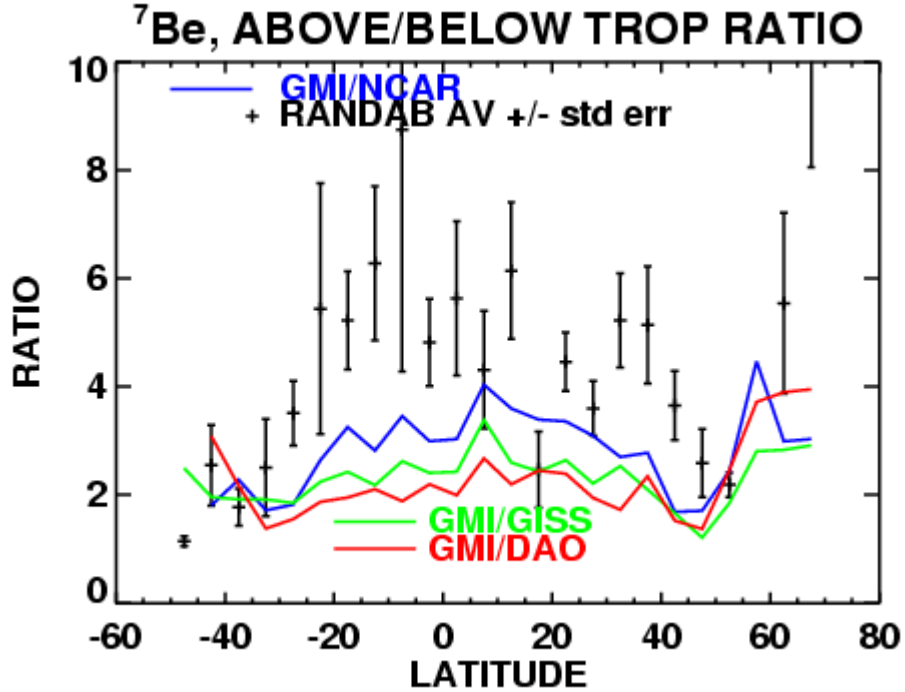

TROPICAL AV OZONE GRADIENT, JULY (PPMV)
GMI/MACCM3
RAQMS GLOBAL
SONDE GRADIENT
+/- STD ERR
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
1
10
100
1000
GRADIENT (PPBV/KM)


MIDLAT AV OZONE GRADIENT, JULY (PPMV)
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
1
10
100
1000
GRADIENT (PPBV/KM)


HILAT AV OZONE GRADIENT, JULY (PPMV)
ALT FROM TROPOPAUSE (KM)
6
4
2
0
-2
-4
-6
1
10
100
1000
GRADIENT (PPBV/KM)


RANDAB AV ^{7}Be, TROP+6 KM
GMI/DAO
GMI/NCAR
GMI/GISS
RANDAB AV +/- std err
^{7}Be (mBq/SCM)
LATITUDE


RANDAB AV ^{7}Be, TROP-6 KM
GMI/NCAR
GMI/GISS
GMI/DAO
RANDAB AV +/- std err
^{7}Be (mBq/SCM)
LATITUDE


^{7}Be, ABOVE/BELOW TROP RATIO
GMI/NCAR
RANDAB AV +/- std err
GMI/GISS
GMI/DAO
RATIO
LATITUDE

Conclusions

1. GMI combined model typically overestimates O3 mixing ratios and gradients in near-tropopause region, both above and below tropopause
   - Best agreement in tropical lower stratosphere
   - Worst agreement in high lat upper troposphere
   - Consistent with excessive STE
   - Vertical resolution/finding tropopause height matters
2. Be-7 above/below tropopause ratios compared to RANDAB observations also consistent with excessive STE
   - MACCM3 has largest ratios and is likely to be best of 3 std met fields
3. Comparison with RAQMS suggests higher resolution/different treatments of vertical transport could produce better UT results
4. Model reproduces observed seasonal cycle of ozone at mid & high latitudes when expressed as % of annual average. Tropical agreement OK